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2ND INTERNATIONAL CONFERENCE ON HYDROCYCLONES, Bath, 19th-21st September 1984,paper E2, pages 177-190, BHRA The Fluid Engineering Centre, Bath, GB; I.C.SMITH et al.: "The effect of split ratio on heavy dispersion liquid-liquidseparation in hydrocyclones"

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Description

This invention relates to a cyclone separator for separating immiscible liquids of different densities, and more particularly to a cyclone separator for removing a smaller volume (e.g. up to 45% by volume of the total) of a heavier liquid, such as water, from a larger volume of a lighter liquid, such as oil, with minimum contamination of the latter. Most cyclone separators are for the purpose of separating heavy solids from a fluid and constraints on their operation are significantly different.

Document WO 86/01130 discloses a cyclone separator which is intended for separation of a mixture of liquids and for obtaining a substantially purer dense phase and comprises

(a) an inlet portion having generally the form of a volume of revolution, and at least one inlet,

(b) an overflow outlet coaxial with the inlet portion,

(c) a generally axially symmetrical converging separation portion adjacent to the inlet portion and on the opposite side from the overflow outlet and having an underflow outlet portion at its narrower end,

wherein the following relationships apply:

(i) $3 < (\pi\ d_2 d_1)/4A_1 < 12$

(ii) $20' < \alpha < 2°$

(iii) $d_o/d_2 < 0.20$

(iiii) $0.9\ d_1 > d_2$

(v) $0.9\ d_2 > d_3$

wherein

d_o is the internal diameter of the overflow outlet,

d_1 is the diameter of the cyclone in the inlet portion where the feed enters, neglecting any inlet channel,

d_2 is the diameter of the cyclone where the inlet portion joins the separation portion

d_3 is the diameter of the cyclone where the separation portion ends,

d_{ix} is twice the radius at which flow enters the cyclone through the x^{th} inlet, measured at entry to the cyclone in a plane parallel to the axis of the cyclone and perpendicular to the component of the inlet centre line not parallel to the cyclone axis,

A_{ix} is the cross-sectional area of the x^{th} inlet,

$$A_i = \sum_{x=1}^{n} A_{ix},$$

$$d_i = \frac{1}{A_i} \sum_{x=1}^{n} d_{ix} A_{ix},$$

and

α is the half angle of convergence of the separation portion.

Paper E2 by Smyth, Thew and Colman presented at the Second International Conference on Hydrocyclones, Bath, England, 19th-21st September, 1984, and reported on pages 177-190 of the Proceedings, discloses a hydrocyclone for such a purpose and suggests that a typical application might be the dewatering of light crude oil at the well head. The hydrocyclone comprises a cylindrical swirl generating chamber with large twin inlets injecting flow at a substantial distance from the axis, a vortex finder and a moderately tapered lower cone.

According to the present invention there is provided a cyclone separator for separation of a mixture of liquids and for obtaining a substantially purer lighter phase and comprising

(a) an inlet portion having generally the form of a volume of revolution, and one or more inlet channels,

(b) a vortex finder outlet, the overflow, coaxial with the inlet portion and projecting into the inlet portion,

(c) a generally axially symmetrical converging separation portion adjacent to the inlet portion and on the opposite side from the vortex finder outlet, and, optionally,

(d) a downstream portion into which the separation portion converges,

the following relationships (i)-(v) applying wherein

d_o is the minimum internal diameter of the vortex finder outlet within $3d_2$ of the inlet plane or at its end if this is not within $3d_2$ of the inlet plane,

d_1 is the diameter of the cyclone in the inlet portion where the feed enters, neglecting any inlet channel,

d_2 is the diameter of the cyclone where the inlet portion joins the separation portion, the junction being as hereinafter defined,

d_3 is the diameter of the cyclone where the separation portion ends or joins the downstream portion, the junction being as hereinafter defined,
d_{ix} is twice the radius at which flow enters the cyclone through the
x^{th} inlet, (i.e., twice the minimum distance of the tangential component of the inlet centre line from the axis),
A_{ix} is the cross-sectional area of the x^{th} inlet, as hereinafter defined,

$$A_i = \sum_{x=1}^{n} A_{ix},$$

$$d_i = \frac{1}{A_i} \sum_{x=1}^{n} d_{ix} A_{ix},$$

and
α is the half angle of convergence of the separation portion as hereinafter defined:
(i)

$$8 \leq \frac{\pi d_2 d_i}{4 A_i} \leq 16$$

(ii) $1° \leq \alpha < 3°$, suitably $1\frac{1}{2}° \leq \alpha < 3°$, conveniently $2° \leq \alpha < 3°$
(iii)

$$0.25 < \frac{d_o}{d_2} < 0.65$$

(iv) $0.9\ d_1 > d_2$
(v) $0.9\ d_2 > d_3$

The inlet plane is defined as the plane perpendicular to the axis of the cyclone at the mean axial position of the weighted areas of the inlets such that the injection of angular momentum into the hydrocyclone is equally distributed axially about it and is thus such that

$$\frac{1}{A_i d_i} \sum_{x=1}^{n} Z_x A_{ix} d_{ix} = 0,$$

wherein Z_x is the axial position of the centre line of the x^{th} inlet.

The junction of the inlet portion and the separation portion is defined as being at the axial position z_2 - (measured away from the inlet plane where $z = 0$) where the condition first applies that:

$$\tan^{-1} \frac{d_2 - d}{2(z - z_2)} < 3° \text{ for all } z > z_2,$$

where
d is the cyclone diameter at z.

The junction of the separation portion and the downstream outlet portion, if present, is defined as the diameter at z_3 where $d/d_3 > 0.98$ for all $z > z_3$.

α is defined as

$$\tan^{-1} \frac{d_2-d_3}{2(z_3-z_2)}$$

A_{ix} is the projection of the cross sectional area of the x^{th} inlet measured at entry to the cyclone in the plane parallel to the cyclone axis which is normal to the plane, also parallel to the cyclone axis, which contains the tangential component of the inlet centre line.

The vortex finder outlet preferably terminates within $3d_2$ of the inlet plane, this distance being defined as l_o.

Preferably the axial overflow outlet, ie, the vortex finder outlet, projects into the cyclone at least as far as the inlet plane.

The expression

$$\frac{\pi d_2 d_1}{4Ai},$$

termed the "swirl coefficient" and designated S, is a reasonable predictor of the ratio of velocities tangentially:axially of flow which has entered the cyclone and which has reached the plane of d_2.

The or each inlet channel is preferably fed from a duct directed substantially tangentially into the inlet portion. Each inlet channel may spiral inwardly in a volute entry. The outer surface of the channel may converge to the diameter of the inlet portion d_1 after

$$\frac{360°}{n}$$

around the axis, wherein n is the number of feed channels.

The inlet channel(s) need not be in a plane normal to the axis and may be offset in a generally helical form. They may attain the diameter d_1 after more than

$$\frac{360°}{n}$$

around the axis. If the inlet portion is itself conical, then the diameter will be approximately d_1.

The convergence averaged from the diameter d_1 measured in the inlet plane to the diameter d_2 may have the greatest cone half-angle θ in the cyclone, which may be in the range 5° to 45°.

The dimensions of the inlet portion should be such that the angular momentum of feed entering from the inlets is substantially conserved into the separation portion.

Preferably d_3/d_2 is less than 0.70 and more preferably less than 0.55.

Preferably d_3/d_2 is greater than 0.20 and more preferably greater than 0.25.

Preferably where the internal length of the downstream outlet portion, if present, is l_3, l_3/d_3 is > l.

For space reasons, it may be desired to curve the downstream outlet gently, and gentle curvature of the cyclone axis is feasible.

d_2 may be regarded as the cyclone diameter and for many purposes can be within the range 10 to 100 mm. With excessively large d_2, the energy consumption becomes large to maintain effective separation while with too small d_2, unfavourable Reynolds number effects and excessive shear stresses can arise.

Pressure drop in the vortex finder should not be excessive, and therefore the length of the "d_o" portion of the vortex finder should be kept low. The vortex finder may reach its "d_o" diameter instantaneously or by any form of abrupt or smooth transition, and may widen thereafter by a taper or step.

Externally, the vortex finder may blend smoothly into the end of the cyclone or may remain cylindrical. It may also carry a skirt or be enlarged towards the end to reduce short circuit flow.

It is possible for at least part of the generator of the inlet portion or of the separation portion or of both to be curved. The generator may be, for example, (i) a monotonic curve (having no points of inflexion) steepest at the inlet-portion end and tending to a cone-angle of zero at its open end, or (ii) a curve with one or more points of inflexion but overall converging towards the downstream outlet portion, preferably never diverging towards the downstream outlet portion.

The cyclone separator is equally effective in any orientation and may be staged in series to improve overall separation. Staging may be applied to either or both outlet streams.

According to another aspect of the present invention there is provided a method for separating a more dense phase from a larger volume of a less dense phase which method comprises supplying a feedstock containing the mixture of the phases to the inlet channel(s) of a cyclone separator as hereinbefore described and recovering an enhanced concentration of the less dense phase from the vortex finder outlet and' an enhanced concentration of the more dense phase from the downstream outlet.

The method is particularly suitable for separating water from oil and in particular, produced water from crude oil, an operation known as dewatering.

The water content can be up to 45% by volume of the total mixture, depending on the nature of the oil.

The split ratio of the cyclone separator may be defined as

$$\frac{\text{volumetric flow rate through downstream outlet}}{\text{volumetric flow rate through inlet}}$$

The split ratio has a minimum value for successful separation which is determined by the geometry of the cyclone, the inlet water concentration, the size distribution of the water droplets and the properties of the oil and water. The cyclone should be operated above this minimum value. This can be achieved by controlling the back pressure by valves or flow restrictions outside the cyclone.

Preferably the split ratio is arranged to exceed 1.2 K_i where K_i is the inlet water content by volume. For optimum performance this may need to be varied as K_i changes.

As liquids normally become less viscous when warm, the method is advantageously performed at as high a temperature as convenient.

The invention will now be described by way of example with reference to the accompanying drawings, in which:-

Figure 1 shows, schematically, a cross-section taken on the axis of a cyclone separator according to the invention, and

Figure 2 is a view down the axis of the cyclone separator. The drawings are not to scale.

A cyclone separator comprises an inlet portion 1, a separation portion 2, a downstream portion 3 and a vortex finder outlet 4, all being coaxial.

The inlet portion 1 is supplied by a single tangential inlet channel 5 and consists essentially of two sections, a cylindrical section 6 of diameter d_1 and length l_1 and a frusto-conical section 7 reducing in diameter from d_1 to d_2. d_2 is regarded as the cyclone diameter. The half angle of taper is θ.

The separation portion 2 is a narrowly tapering cylinder the diameter of which reduces from d_2 where it adjoins the frusto-conical section 7 to d_3 where it adjoins the downstream portion 3. The half angle of taper is α.

The downstream portion 3 is a cylinder of diameter d_3 and length l_3.

The vortex finder outlet is a cylinder of internal diameter d_o which projects beyond the axial plane of the inlet 8.

In the cyclone separator described, dimensions are rounded to the nearest millimetre and relationships are as follows:

d_2 is taken as the standard diameter and is 36 mm.

$d_o = 0.28\ d_2 = 10$ mm

$d_1 = 1.94\ d_2 = 69$ mm

$d_3 = 0.27\ d_2 = 10$ mm

$l_1 = 1.9\ d_2 = 68$ mm

$l_3 = 2\ d_2 = 70$ mm

$l_o = 0.38\ d_2 = 14$ mm

diameter of circular inlet = 0.36 d_2 = 13 mm

distance of axis of inlet below top of inlet chamber = 0.18 d_2 = 6.5 mm

$\theta = 40°$

$\alpha = 2°$

$$S = \frac{\pi d_1 d_2}{4A_1} = 12.$$

$0.9\ d_1 = 62$
$0.9\ d_2 = 32$

Example 1

The cyclone described above was operated at approximately 20 °C with kerosine containing dispersions of water at an overall throughput of 45 l/min. At a split ratio of 40% an inlet water content of 25% by volume (mean drop size 115 um) was reduced to 0.14% in the overflow outlet while at a split ratio of 10% an inlet water content of 5% (mean dropsize 45 um) was reduced to 0.13% in the overflow outlet. The pressure drops to the overflow outlet were 2 bar and 1.5 bar respectively.

Examples 2 & 3

Further tests were carried out with a cyclone the same as in Example 1 except that $\alpha = 1\frac{1}{2}°$. Operating conditions and results are set out in the accompanying Table.

EX	OIL TYPE	NATURE OF WATER/ OIL SYSTEM	DEWATERING PERFORMANCE FOR $K_i \leq$ 30% at OPTIMUM SPLIT	OPERATING RANGE FOR BEST DE-WATERING (see adjacent column)	
				FLOWRATE (l/min)	PRESSURE DROP (bar)
2	Kerosine $\nu \simeq 2$cSt $\rho \simeq 780$ kgm^{-3}	drops readily coalesce, low surfactant levels; γ = 23-28 mN m^{-1}	$K_u \leqslant 0.4\%$ [$\bar{d}_i$ = 45 → 130μ as K_i = 5 → 30%]	40-75	1.1-3.5
3	Kerosine/Heavy Gas Oil Blend $\nu \simeq 4$cSt $\rho \simeq 820$ Kgm^{-3}	restricted drop coalescence rate, moderate surfactant levels; $\gamma \simeq 23$ mN m^{-1}	$K_u/K_i \leqslant 0.13$ [$\bar{d}_i$ = 25-70μ as K_i = 5 → 30%]	37-57	0.7-2.5

K_i inlet water concentration (vol)
K_u upstream or overflow water concentration (vol)
$\bar{d}_i$ mean drop size at inlet
γ interfacial tension
ν kinematic viscosity
ρ density

Test Temperatures : 20-25°C

The following Table shows examplary geometries for further cyclone separators constructed in accordance with the invention.

	A	B	C
d_2	35.0 mm	35.0 mm	35.0 mm
d_o/d_2	0.420	0.280	0.420
A_I	126 mm^2	192 mm^2	192 mm^2
d_3/d_2	0.268	0.268	0.500
d_1/d_2	1.98	1.74	1.74
l_o/d_2	0.38	0.41	0.41
l_1/d_2	1.94	1.00	1.00
l_3/d_2	1.35	1.35	2.50
θ	45°	45°	20°
α	1.5°	1.5°	1.5°
Swirl co-efficient	12.0	9.8	9.8
Inlet type	single, tangential, circular	single, volute, rectangular 3:1	single, volute, rectangular 3:1

A, B and C relate specifically to cyclone separators suitable for handling mixture of 5% water in oil, 20% water in oil and 40% water in oil, respectively.

Claims

1. A cyclone separator comprising:

(a) an inlet portion (1) having generally the form of a volume of revolution, and at least one inlet (5),

(b) an overflow coaxial with the inlet portion (1),

(c) a generally axially symmetrical converging separation portion (2) adjacent to the inlet portion (1) and on the opposite side from the overflow outlet and having an underflow outlet portion (31) at its narrower end,

wherein the following relationships apply:

(i) $3 < (\pi d_2 d_1)/4A_1 < 12$

(ii) $20' < \alpha < 2°$

(iii) $0.9\ d_1 > d_2$

(iv) $0.9\ d_2 > d_3$

wherein

d_o is the internal diameter of the overflow outlet,

d_1 is the diameter of the cyclone in the inlet portion (1) where the feed enters, neglecting any inlet channel (8),

d_2 is the diameter of the cyclone where the inlet portion (1) joins the separation portion (2),

d_3 is the diameter of the cyclone where the separation portion (2) ends,

d_{ix} is twice the radius at which flow enters the cyclone through the x^{th} inlet,

A_{ix} is the cross-sectional area of the x^{th} inlet, measured at entry to the cyclone in a plane parallel to the axis of the cyclone and perpendicular to the component of the inlet centre line not parallel to the cyclone axis,

$$A_i = \sum_{x=1}^{n} A_{ix},$$

$$d_i = \frac{1}{A_i} \sum_{x=1}^{n} d_{ix} A_{ix},$$

and

α is the half angle of convergence of the separation portion,

characterised in that

(a) a vortex finder outlet (4) projects into the inlet portion and d_o is the minimum internal diameter of the vortex finder outlet (4) within $3d_2$ of the inlet plane or at its end if this is not within $3d_2$ of the inlet plane; and

(b) the following relationships apply:

$8 \leq (\pi d_2 d_1))/4A \leq 16$

$1° \leq \alpha < 3°$

$0.25 < d_o/d_2 < 0.65$

2. A cyclone separator according to claim 1 wherein $2° \leq \alpha < 3°$.

3. A cyclone separator according to claim 1 wherein $1\frac{1}{2}° \leq \alpha < 3°$.

4. A cyclone separator according to any of the preceding claims comprising a downstream outlet portion (3) into which the separation portion (2) converges.

5. A cyclone separator according to any of the preceding claims wherein the vortex finder outlet (4) terminates within $3d_2$ of the inlet plane.

6. A cylone separator according to any of the preceding claims wherein the or each inlet channel (5) is fed from a duct directed substantially tangentially into the inlet portion.

7. A cyclone separator according to any of the preceding claims wherein d_3/d_2 is in the range 0.20 to 0.70.

8. A cyclone separator according to claim 7 wherein d_3/d_2 is in the range 0.25 to 0.55.

9. A cyclone separator according to any of claims 4 to 8 wherein l_3/d_3 is greater than 1, wherein l_3 is the internal length of the downstream outlet portion.

10. A method of separating a more dense phase from a larger volume of a less dense phase which method comprises supplying a feedstock containing the mixture of the phases to the inlet channel(s) (5) of a cyclone separator according to any of the preceding claims and recovering an enhanced concentration of the less dense phase from the vortex finder outlet (4) and an enhanced concentration of the more dense phase from the separation portion (2) or the downstream outlet (3).

11. A method according to claim 10 wherein the more dense phase is water and the less dense phase is oil.

12. A method according to claim 11 wherein the water content is up to 45% by volume of the mixture.

13. A method according to either of claims 11 or 12 wherein the split ratio exceeds 1.2 K_i where K_i is the inlet water content by volume.

Patentansprüche

1. Zyklonabscheider umfassend:
   (a) einen Einlaßbereich (1), welcher allgemein die Form eines Rotationsvolumens und wenigstens einen Einlaß (5) aufweist,
   (b) einen Überlauf, welcher koaxial mit dem Einlaßbereich (1) ausgebildet ist,
   (c) einen im wesentlichen sich axialsymmetrisch verengenden Abscheidebereich (2), welcher benachbart zu dem Einlaßbereich (1) und gegenüberliegend von dem Überlaufauslaß ausgebildet ist und welcher einen Unterlaufauslaßbereich (31) an seinem schmäleren Ende aufweist,
   worin die folgenden Beziehungen vorgesehen sind:
   (i) $3 < (\pi d_2 d_1)/4A_1 < 12$
   (ii) $20' < \alpha < 2°$
   (iii) $0{,}9\, d_1 > d_2$
   (v) $0{,}9\, d_2 > d_3$
   worin
   d_0 der Innendurchmesser des Überlaufauslasses ist,
   d_1 der Durchmesser des Zyklons im Einlaßbereich (1) ist, in welchem das zugeführte Material eintritt, wobei jeder Einlaßkanal (8) unberücksichtigt gelassen wird,
   d_2 der Durchmesser des Zyklons im Bereich, wo der Einlaßbereich (1) an den Abscheidebereich (2) anschließt, ist,
   d_3 der Durchmesser des Zyklons im Bereich, wo der Abscheidebereich (2) endet, ist,

d_{ix} zweimal der Radius ist, bei welchem der Zufluß in den Zyklon durch den x-ten Einlaß eintritt, A_{ix} der Querschnittsbereich des x-ten Einlaßes ist, gemessen am Eintritt in den Zyklon in einer Ebene, welche parallel zu der Achse des Zyklons und normal zu der Komponente der Einlaßmittellinie liegt, welche nicht parallel zu der Zyklonachse liegt,

$$A_i = \sum_{x=1}^{n} A_{ix},$$

$$d^i = \frac{1}{A_i} \sum_{x=1}^{n} d_{ix} A_{ix},$$

und
α der halbe Verengungswinkel des Abscheidebereiches ist,
dadurch gekennzeichnet,
daß (a) ein Wirbel-Führungsauslaß (4) in den Einlaßbereich ragt und d_0 der minimale innere Durchmesser des Wirbel-Führungsauslasses (4) in $3d_2$ der Einlaßebene oder an seinem Ende, wenn er nicht in $3d_2$ der Einlaßebene ist, ist; und (b) die folgenden Beziehungen vorgesehen sind:
$8 \leqq (\pi\, d_2 d_1)/4A \leqq 16$
$1° \leqq \alpha < 3°$
$0{,}25 < d_0/d_2 < 0{,}65$

2. Zyklonabscheider nach Anspruch 1, worin $2° \leqq \alpha < 3°$.

3. Zyklonabscheider nach Anspruch 1, worin $1{,}5° \leqq \alpha < 3°$.

4. Zyklonabscheider nach einem der vorhergehenden Ansprüche umfassend einem stromabwärts gelegenen Auslaßbereich (3), zu welchem der Anscheidebereich (2) sich verjüngt.

5. Zyklonabscheider nach einem der vorhergehenden Ansprüche, worin der Wirbel-Führungsauslaß (4) in $3d_2$ der Einlaßebene endet.

6. Zyklonabscheider nach einem der vorhergehenden Ansprüche, worin der oder jeder Einlaßkanal (5) von einer Leitung, welche im wesentlichen tangential zu dem Einlaßbereich verläuft, gespeist ist.

7. Zyklonabscheider nach einem der vorhergehenden Ansprüche, worin d_3/d_2 im Bereich von 0,20 bis 0,70 liegt.

8. Zyklonabscheider nach Anspruch 7, worin d_3/d_2 im Bereich von 0,25 bis 0,55 liegt.

9. Zyklonabscheider nach einem der Ansprüche 4 bis 8, worin l_3/d_3 größer als 1 ist, worin l_3 die innere Länge des stromabwärts gelegenen Auslaßbereiches ist.

10. Verfahren zum Trennen einer dichteren Phase von einem größeren Volumen einer weniger dichten Phase, welches Verfahren das Zuführen eines Materials, enthaltend die Mischung der Phasen zu dem Einlaßkanal(kanälen) (5) eines Zyklonabscheiders, gemäß einem der vorhergehenden Ansprüche, und die Rückgewinnung einer vergrößerten Konzentration der weniger dichten Phase aus dem Wirbel-Führungsauslaß (4) und einer vergrößerten Konzentration der dichteren Phase aus dem Abscheidebereich (2) oder dem stromabwärts gelegenen Auslaß (3) umfaßt.

11. Verfahren nach Anspruch 10, worin die dichtere Phase Wasser ist und die weniger dichte Phase Öl ist.

12. Verfahren nach Anspruch 11, worin der Wassergehalt bis zu 45 Vol-% der Mischung beträgt.

13. Verfahren nach Anspruch 11 oder 12, worin die Trennungsrate 1,2 K_l übersteigt, worin K_l der Einlaß-Wassergehalt in Volumsteilen ist.

Revendications

1. Séparateur à cyclone, comprenant :
   (a) une partie d'entrée (1) ayant la forme générale d'un volume de révolution, et au moins une entrée (5),
   (b) un déversoir coaxial à la partie d'entrée (1),
   (c) une partie convergente (2) de séparation ayant une symétrie générale axiale, adjacente à la partie (1) d'entrée et du côté opposé à la sortie du déversoir et ayant une partie de sortie (31) de soutirage à son extrémité relativement étroite,
   les relations suivantes s'appliquant :
   (i) $3 < (\pi d_2 d_1)/4A_1 < 12$
   (ii) $20' < \alpha < 2°$
   (iii) $0{,}9d_1 > d_2$
   (iv) $0{,}9d_2 > d_3$
   d_0 étant le diamètre interne de la sortie de débordement,
   d_1 étant le diamètre du cyclone à la partie d'entrée (1) par laquelle pénètre la charge, compte non tenu d'un canal éventuel d'entrée (8), d_2 étant le diamètre du cyclone à l'endroit où la partie d'entrée (1) se raccorde à la partie de séparation (2), d_3 étant le diamètre du cyclone à l'endroit où la partie de séparation (2) se termine, d_{ix} étant le double du rayon auquel pénètre le courant dans le cyclone par la x^e entrée, A_{ix} étant la section de la x^e entrée, mesurée à l'entrée du cyclone dans un plan parallèle à l'axe du cyclone et perpendiculaire à la composante de l'axe central d'entrée qui n'est pas parallèle à l'axe du cyclone,

$$A_i = \Sigma_{x=1}^{n} d_{ix} A_{ix},$$

   et
   α est le demi-angle de convergence de la partie de séparation,
   caractérisé en ce que
   (a) une sortie (4) de détermination de tourbillon dépasse dans la partie d'entrée et d_0 est le diamètre interne minimal de la sortie (4) de détermination de tourbillon à une distance inférieure à $3d_2$ du plan d'entrée ou de son extrémité si elle n'est pas à une distance inférieure à $3d_2$ du plan d'entrée, et
   (b) les relations suivantes s'appliquent
   $8 \leq (\pi d_2 d_1)/4A \leq 16$
   $1° \leq \alpha < 3°$
   $0{,}25 < d_o/d_2 < 0{,}65$.

2. Séparateur à cyclone selon la revendication 1, dans lequel $2° \leq \alpha < 3°$.

3. Séparateur à cyclone selon la revendication 1, dans lequel $1{,}5° \leq \alpha < 3°$.

4. Séparateur à cyclone selon l'une quelconque des revendications précédentes, comprenant une partie (3) de sortie aval dans laquelle converge la partie de séparation (2).

5. Séparateur à cyclone selon l'une quelconque des revendications précédentes, dans lequel la sortie (4) de détermination de tourbillon se termine à une distance inférieure à $3d_2$ du plan d'entrée.

6. Séparateur à cyclone selon l'une quelconque des revendications précédentes, dans lequel le canal ou chaque canal d'entrée (5) est alimenté par un conduit qui a une direction pratiquement tangentielle dans la partie d'entrée.

7. Séparateur à cyclone selon l'une quelconque des revendications précédentes, dans lequel d_3/d_2 est compris entre 0,20 et 0,70.

8. Séparateur à cyclone selon la revendication 7, dans lequel d_3/d_2 est compris entre 0,25 et 0,55.

9. Séparateur à cyclone selon l'une quelconque des revendications 4 à 8, dans lequel l_3/d_3 est supérieur à 1, l_3 étant la longueur interne de la partie de sortie aval.

10. Procédé de séparation d'une phase relativement dense d'un volume plus grand d'une phase relativement moins dense, le procédé comprenant la transmission d'une charge contenant le mélange des phases vers un ou plusieurs canaux d'entrée (5) d'un séparateur à cyclone selon l'une quelconque des revendications précédentes, et la récupération avec une plus grande concentration de la phase relativement moins dense à la sortie (4) de détermination de tourbillon et une plus grande concentration de la phase relativement plus dense à la partie (2) de séparation ou à la sortie aval (3).

11. Procédé selon la revendication 10, dans lequel la phase relativement plus dense est de l'eau et la phase relativement moins dense du pétrole.

12. Procédé selon la revendication 11, dans lequel la teneur en eau est inférieure ou égale à 45 % en volume du mélange.

13. Procédé selon l'une des revendications 11 et 12, dans lequel le rapport de séparation est supérieur à 1,2 K_l, K_l étant la teneur volumique en eau à l'entrée.

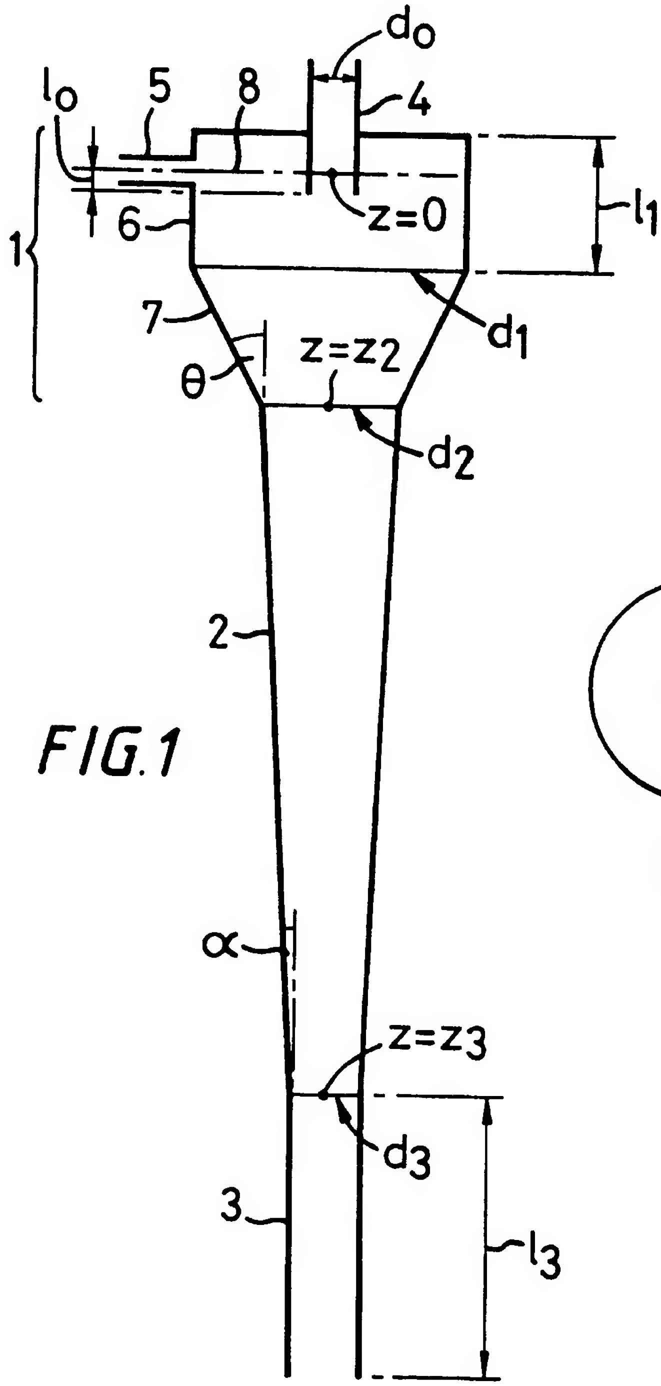

FIG.1

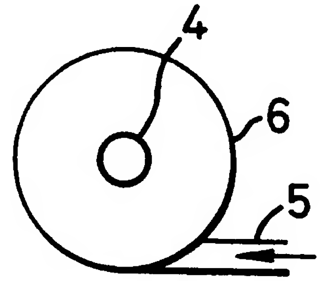

FIG. 2